



“Advanced Airport Data Link” - Concept and Demonstrator Implementation for a Modern Airport Data Link

**Erik Haas
Michael Schnell**

German Aerospace Center - DLR
Institute for Communications and Navigation
Communications Systems Department
Site Oberpfaffenhofen

Presented at: ICNS Conference 2003, Annapolis, MD, May 2003

Table of Contents



- Introduction
- TARMAC Research Activity
- Advanced Airport Data Link (ADL)
- Principle of MC-CDMA
- ADL Concept Based on MC-CDMA
- ADL Demonstrator
- Conclusions and Outlook

Introduction



- Continuous increase in air traffic load
 - Approximately doubled in 2015
 - Bottlenecks in air traffic handling especially on ground
- Countermeasure: Improve throughput on airports
 - Modern surveillance and guidance means necessary
 - Advanced Surface Movement Guidance and Control System (A-SMGCS)
 - Efficient communication link between tower and aircraft
 - Provide necessary data transfer for A-SMGCS
 - Provide necessary user capacity
 - Provide required reliability
- **Advanced Airport Data Link (ADL)**
 - Designed to fulfil A-SMGCS requirements
 - Concept and demonstrator implementation

TARMAC Research Activity



- TARMAC (Taxi and Ramp Management and Control)
 - DLR contribution to A-SMGCS development
 - Co-operation with EU projects
 - DEFAMM: Demonstration Facilities for Airport Movement Management
 - BETA: Operational Benefits of Testing an A-SMGCS
- Key goals of TARMAC
 - Decreasing environmental impact of running engines by decreasing waiting times of aircraft
 - Improving overall throughput on airports by planning routes from runways to gates and vice versa
 - Improving situation awareness of pilots and, thus, improving safety on airports

TARMAC Research Activity



- Key elements of TARMAC
 - Improved planning system which maximises overall throughput on airports
 - Improved and new sensors for determination of aircraft and ground vehicle positions
 - Improved sensor data fusion which takes into account the measurement results of all sensors
 - Improved guidance means and HMIs (Human Machine Interfaces)
 - Improved information exchange between pilots and controllers using an advanced airport data link

Advanced Airport Data Link



- Main requirements
 - High transmission bit rate, at least 128 kbit/s per user
 - High user capacity, at least 100 simultaneously active users
 - Large coverage area, 50-100 km around airport
 - Data link available during take-off and landing
 - Connection to airport intranet
 - Expansion toward additional services, e.g. catering orders, airline instructions, aircraft attendance information exchange
 - Different priorities for different kinds of services
 - Flexibility of physical layer
 - Exchange between user capacity and transmission bit rate

Advanced Airport Data Link



- Consequences
 - Large transmission bandwidth due to
 - high transmission bit rate
 - high user capacity
 - New frequency band (C band) due to
 - extensive use of VHF band
 - large transmission bandwidth
 - Adaptation to channel characteristics due to
 - fading environment and Doppler shift/spread
- Proposed transmission scheme
 - Choice with respect to requirements and consequences
 - Ground/Air link: **MC-CDMA**
 - Air/Ground link: Under consideration

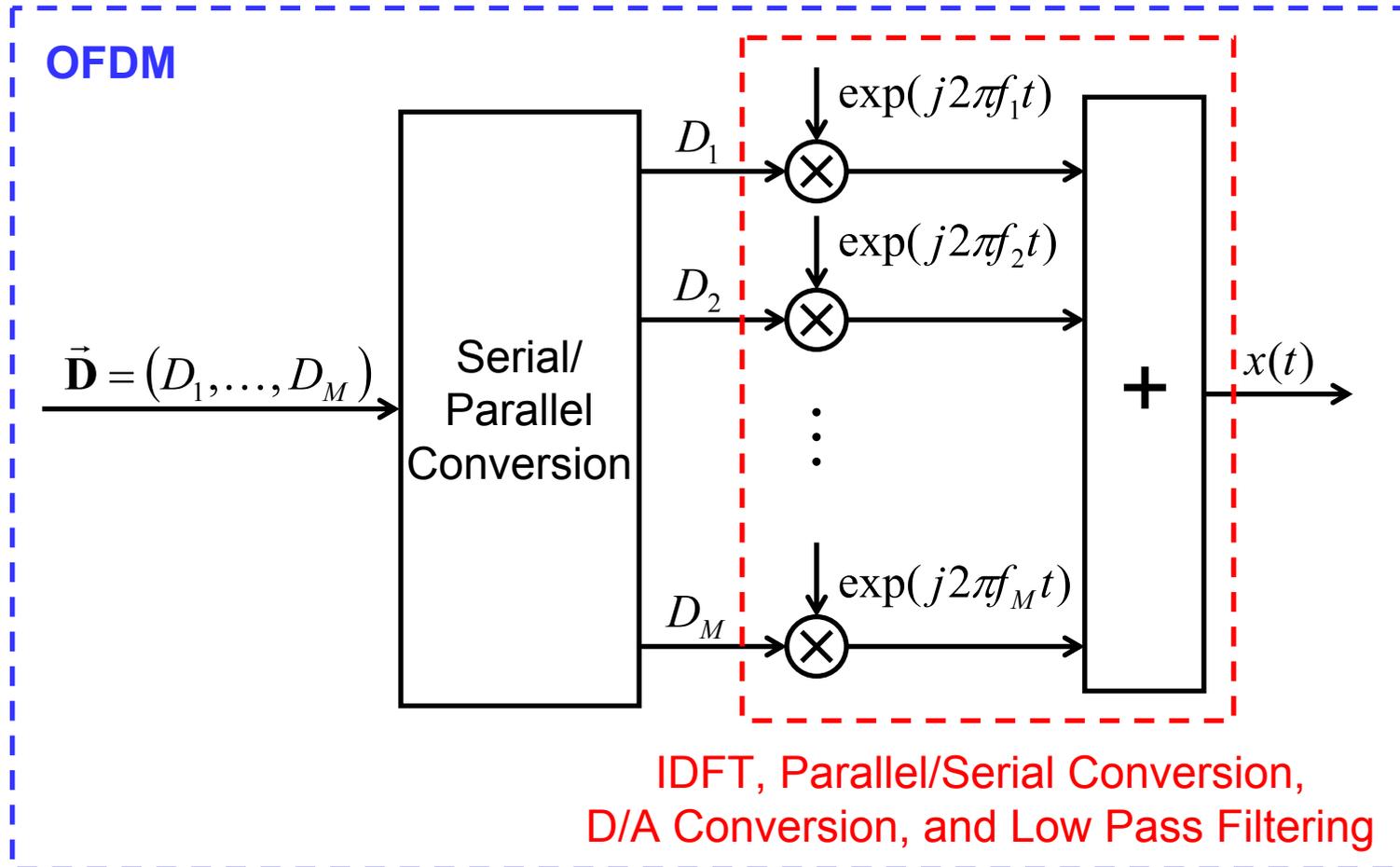
Principle of MC-CDMA



- What is MC-CDMA?
 - “Multi-Carrier Code-Division Multiple-Access”
 - Combination of **OFDM** (“Orthogonal Frequency-Division Multiplexing”) and **CDMA**
 - OFDM: High-rate data transmission (DAB, DVB-T, IEEE 802.11a)
 - CDMA: High capacity multiple-access scheme (UMTS, IMT2000)
 - Highly flexible scheme for high-rate data transmission
 - Fulfills the requirements of modern A-SMGCS systems
 - Under discussion as physical layer technology for Fourth Generation (“4G”) mobile radio systems

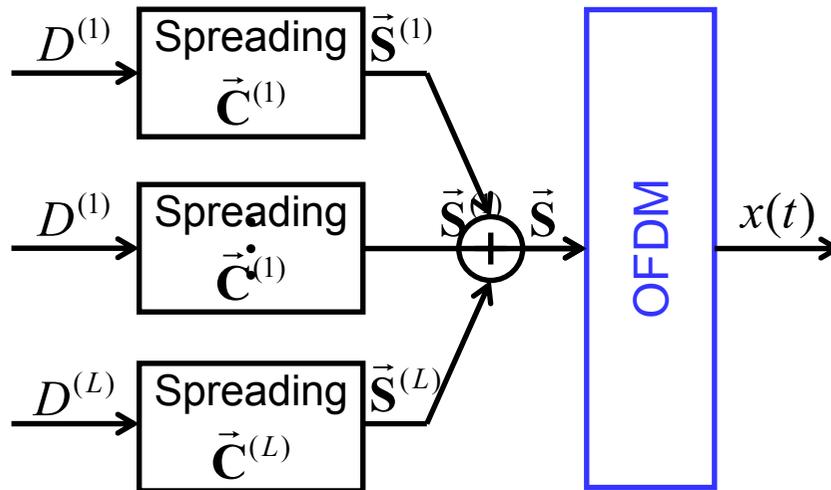
Principle of MC-CDMA

- How does OFDM work?



Principle of MC-CDMA

- How does MC-CDMA work?

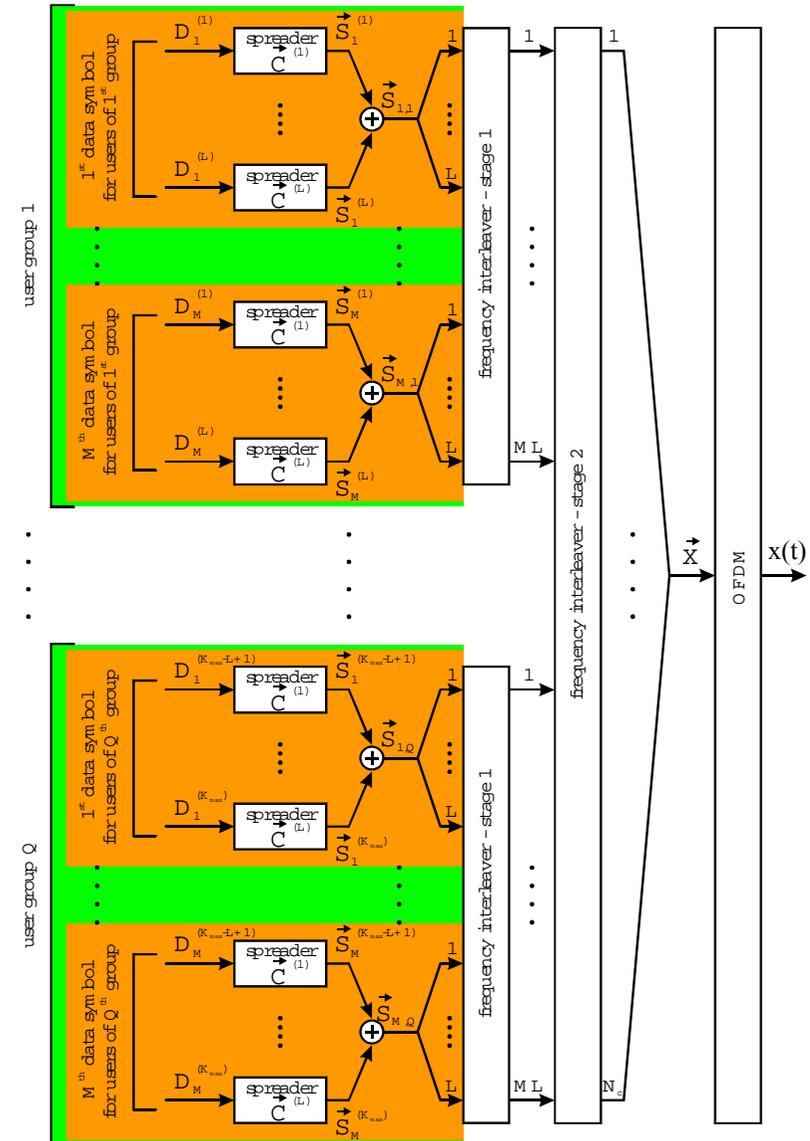


- Consider ground/air link
- Several users occupy the same set of subcarriers
- Different orthogonal spreading sequences ' $\mathbf{C}^{(\cdot)}$ ' are used to separate the users
- The spreading sequences are Walsh-Hadamard codes
- Maximum number of users $K_{\max} = L$
- Number of subcarriers $N_c = L$

Principle of MC-CDMA



- MC-CDMA with M&Q Modification
 - Extension to **Q** independent **user groups**
 - All users in each user group transmit **M** data symbols
 - Maximum number of users $K_{\max} = QL$
 - Number of subcarriers $N_c = QML$



ADL Concept Based on MC-CDMA

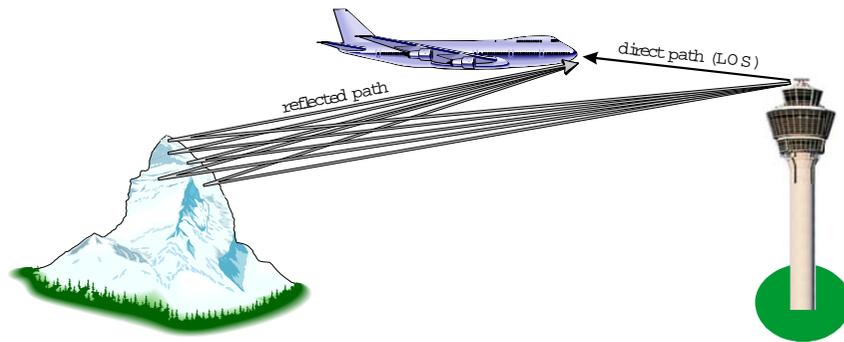


- Aeronautical Transmission Channel
 - Development of different aeronautical channel scenarios
 - Channel scenarios used for MC-CDMA design
 - Parameter choice
 - Evaluation of ADL concept by computer simulations
- Main Parameters & Characteristics of ADL
 - Operational ADL
 - Demonstrator ADL
- MC-CDMA Frame Structure
- Simulation Results for Different Channel Scenarios

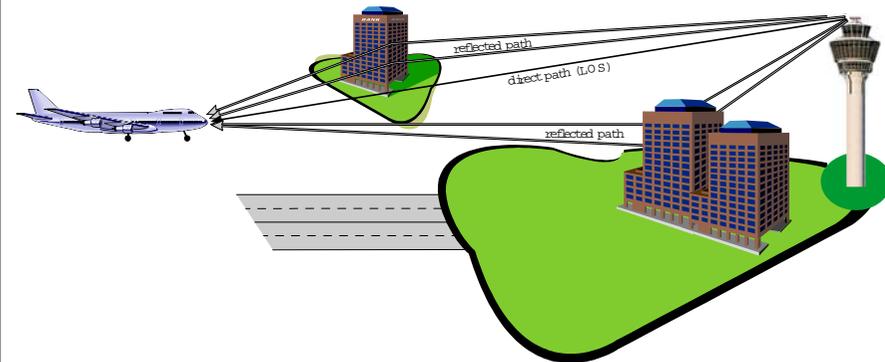
Aeronautical Channel Scenarios



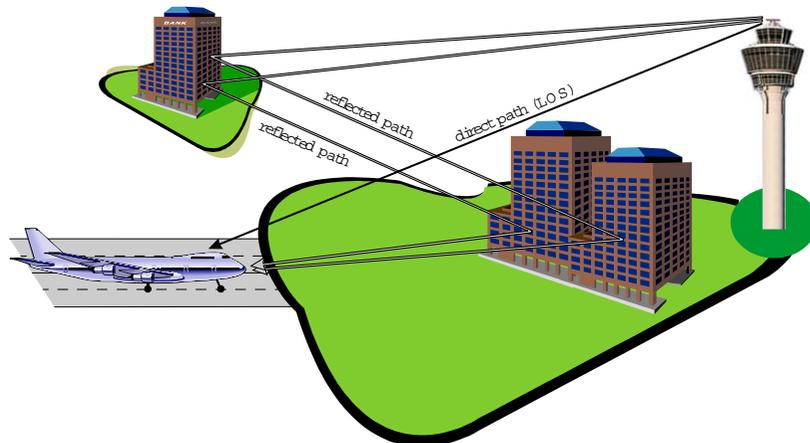
En-Route (ground-air)



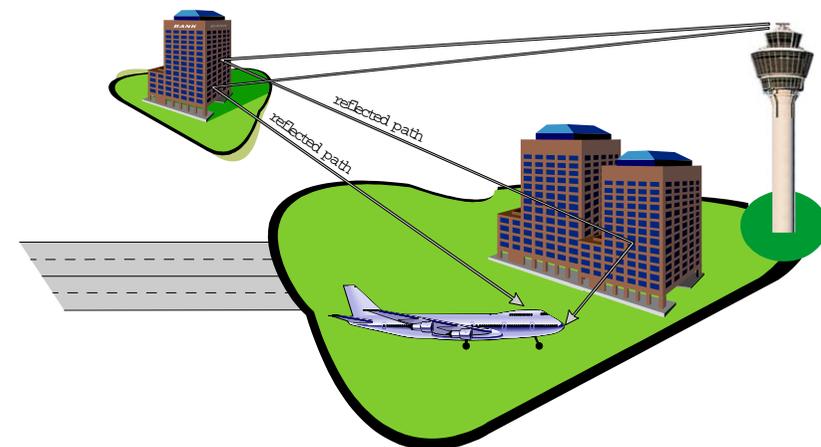
Arrival (ground-air)



Taxi (ground-ground)



Parking (ground-ground)



Aeronautical Channel Parameters



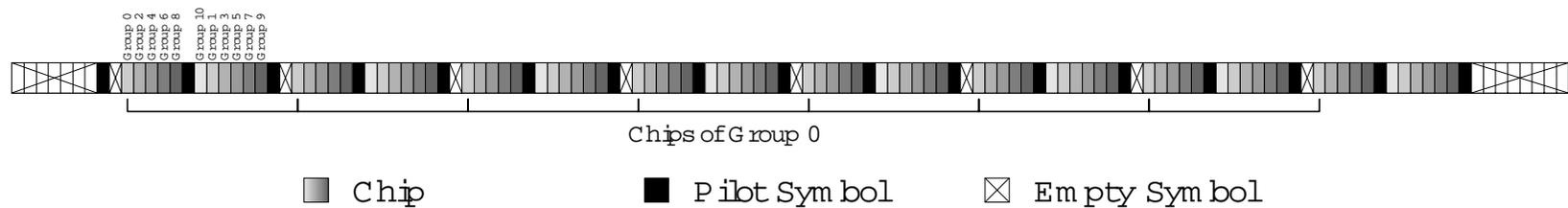
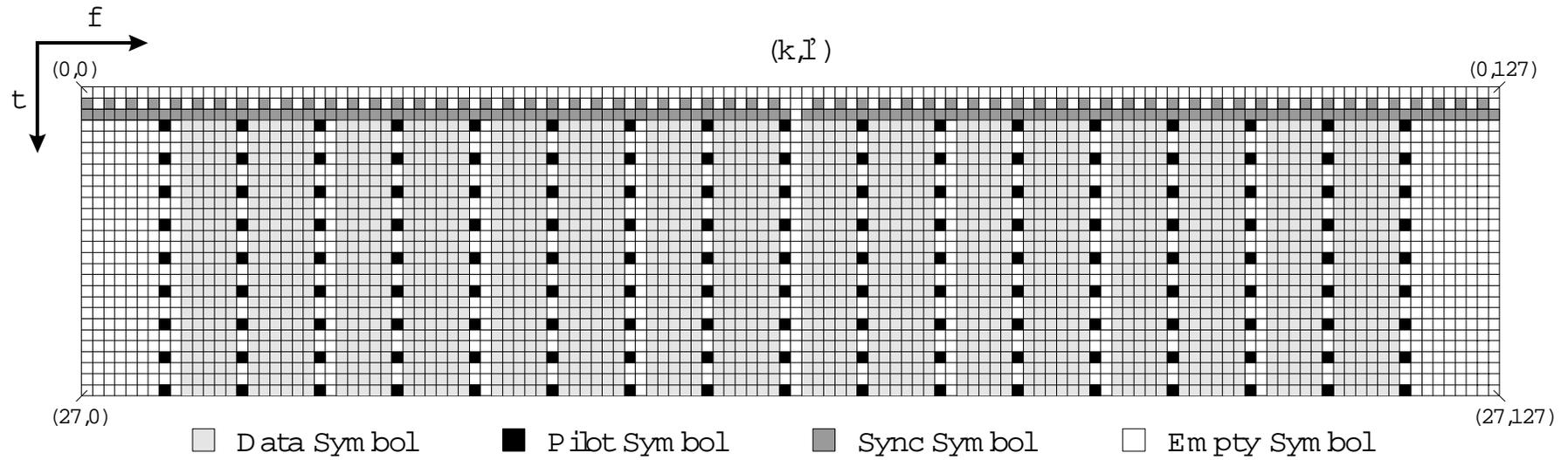
	Parking Scenario	Taxi Scenario	Arrival Scenario	En-Route Air-Ground (Air-Air)
Maximum velocity v_{\max} [m/s]	5.5	15.0	150.0	440.0 (620.0)
Maximum delay τ_{\max} [s]	7.0e-6	0.7e-6	7.0e-6	33.0e-6 (66.0e-6)
Number of echo paths N	20	20	20	20
Rice factor K [dB]	-1000.0	6.9	15.0	15.0
$f_{\text{DLOS}}/f_{\text{Dmax}}$ factor	0.0	0.7	1.0	1.0
Start angle φ_L of beam [°]	0.0	0.0	-90.0	178.25
End angle φ_H of beam [°]	360.0	360.0	+90.0	181.75
Exponential or two-ray delay model ?	exponential	exponential	exponential	two-ray
Slope time τ_{slope} for exponential delay [s]	1.0e-6	0.1087e-6	1.0e-6	-

Main Parameters & Characteristics

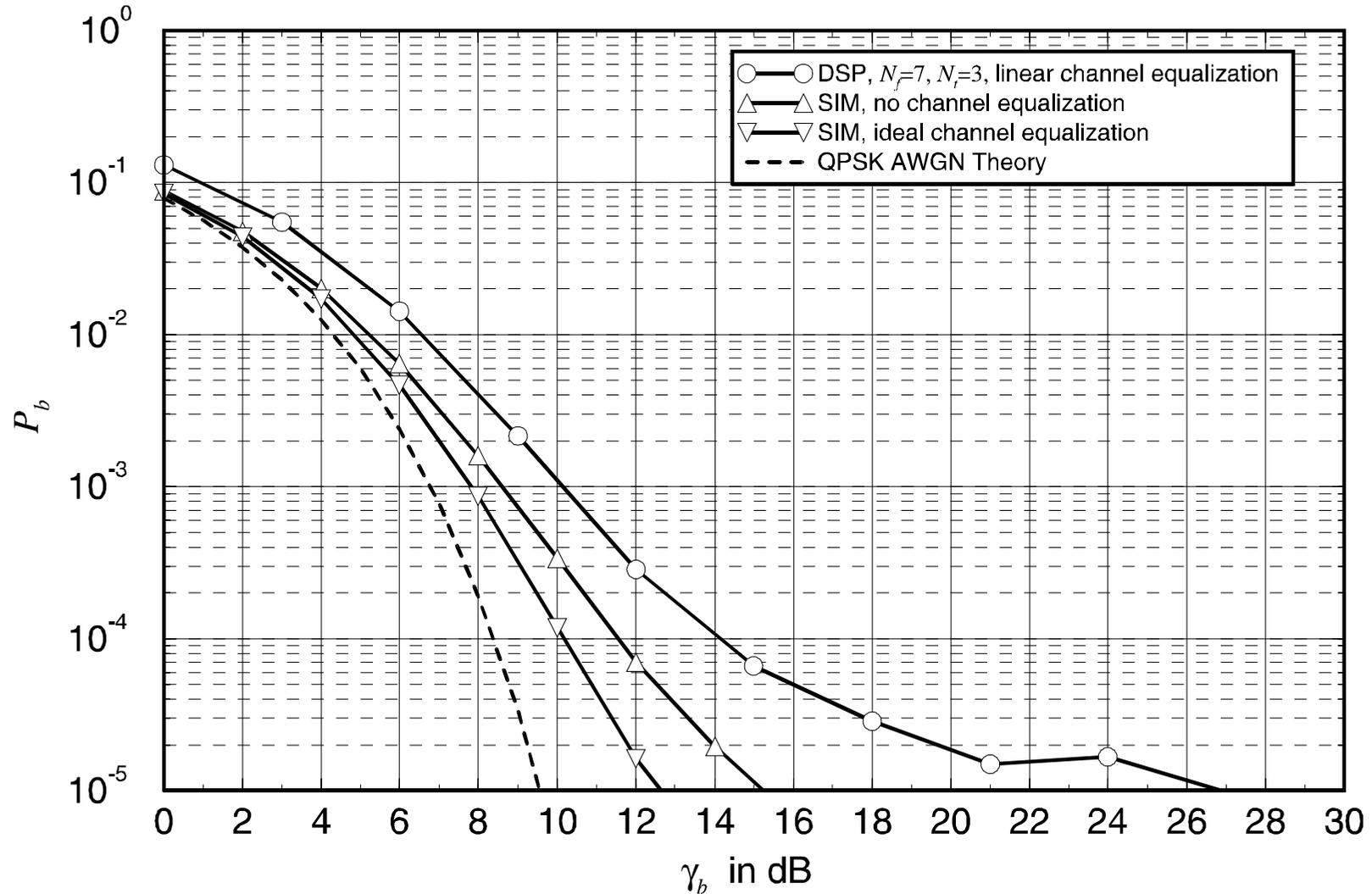


Main Parameters:	Operational ADL	Demonstrator ADL
Carrier frequency	5.1465 GHz	5.1465 GHz
Bandwidth	8192 kHz	512 kHz
Number of subcarriers	2048	128
Subcarrier spacing	4 kHz	4 kHz
OFDM symbol duration	250 μ s	250 μ s
Guard interval duration	10 μ s	10 μ s
Modulation type	QPSK	QPSK
Spreading length	8	8
Main Characteristics:		
Number of users	128 ... 8	64 ... 8
Bit rate per user	128 ... 2048 kbit/s	16 ... 128 kbit/s

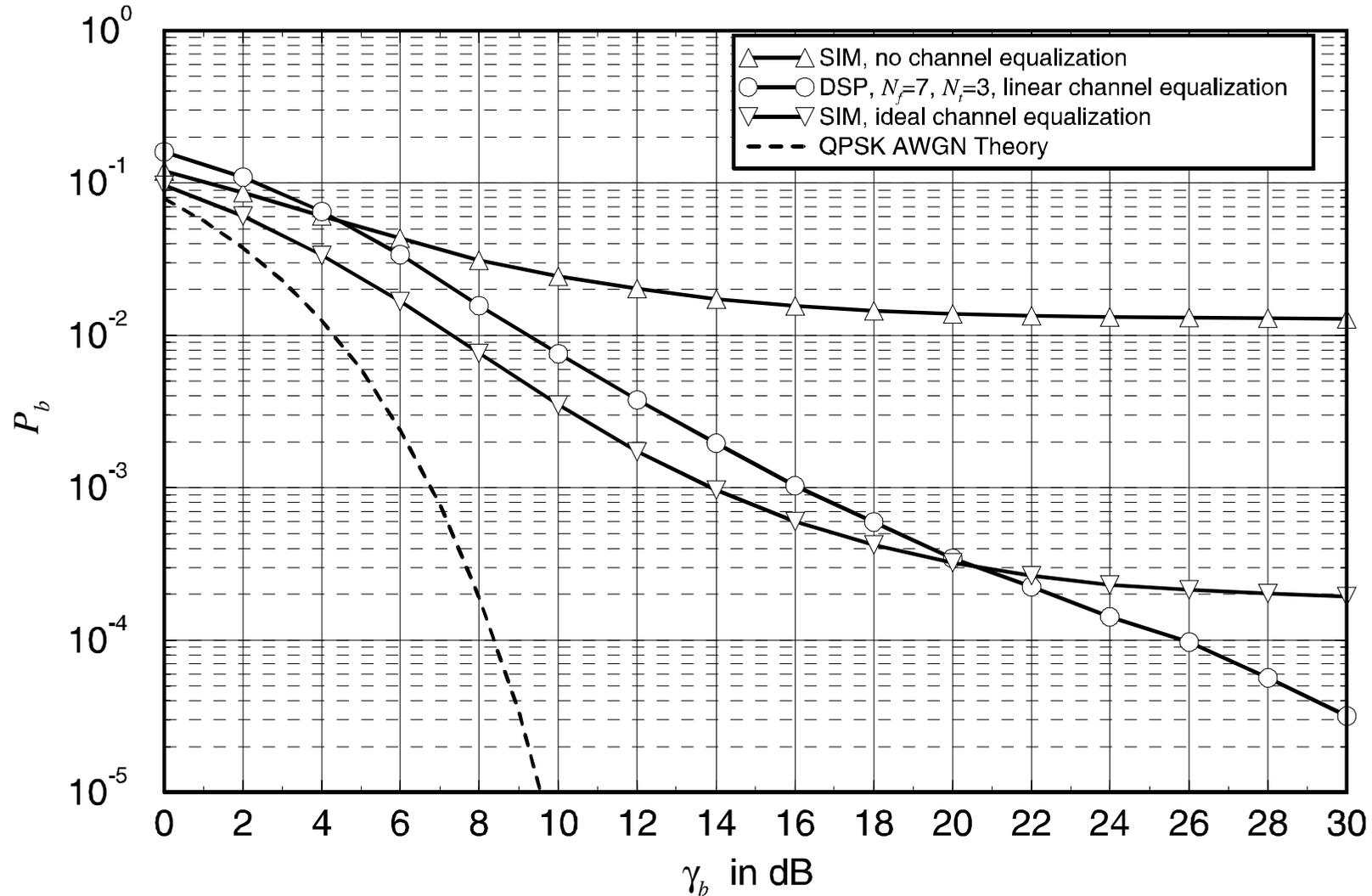
MC-CDMA Frame Structure



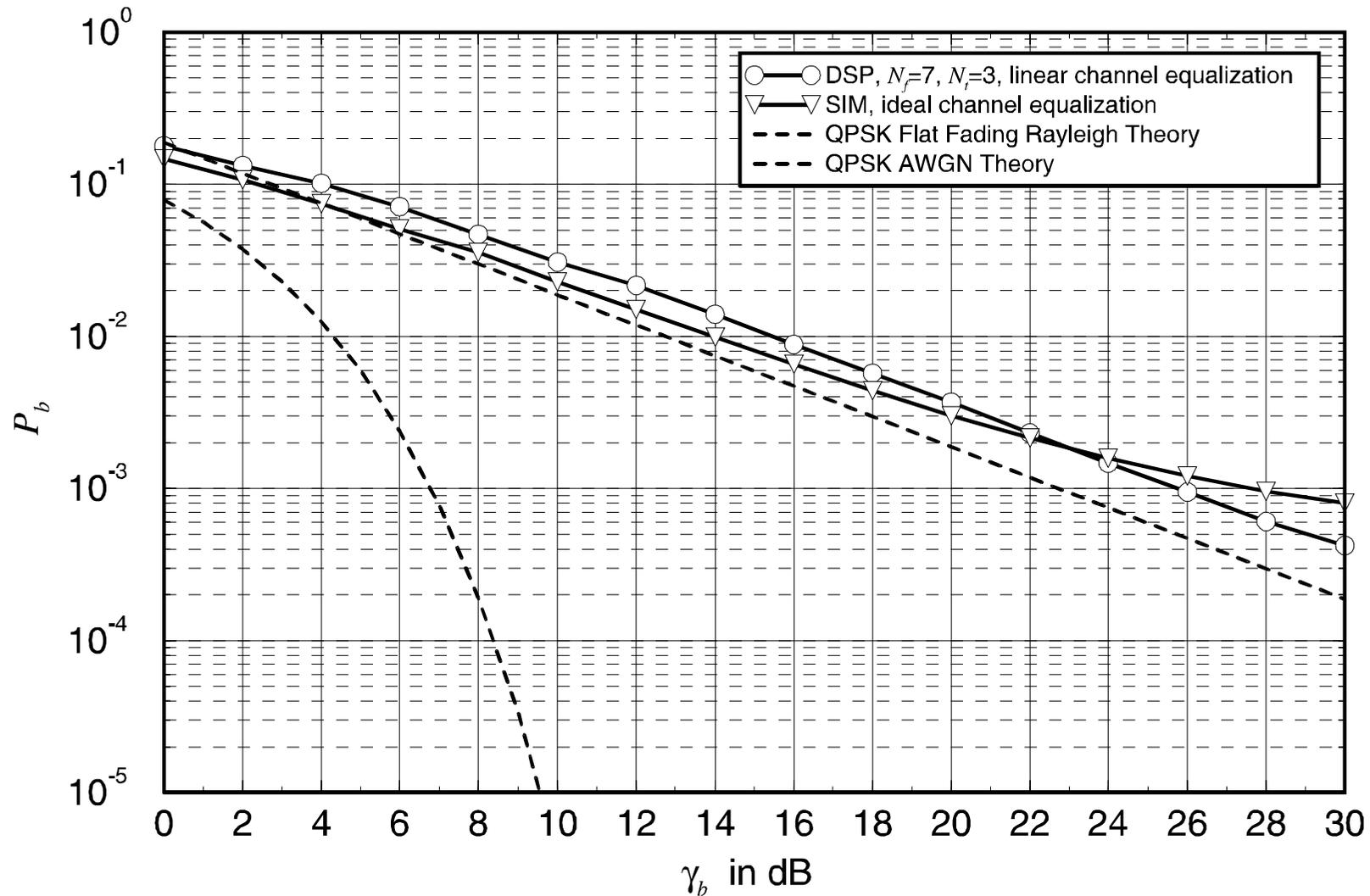
Arrival Channel QPSK Performance



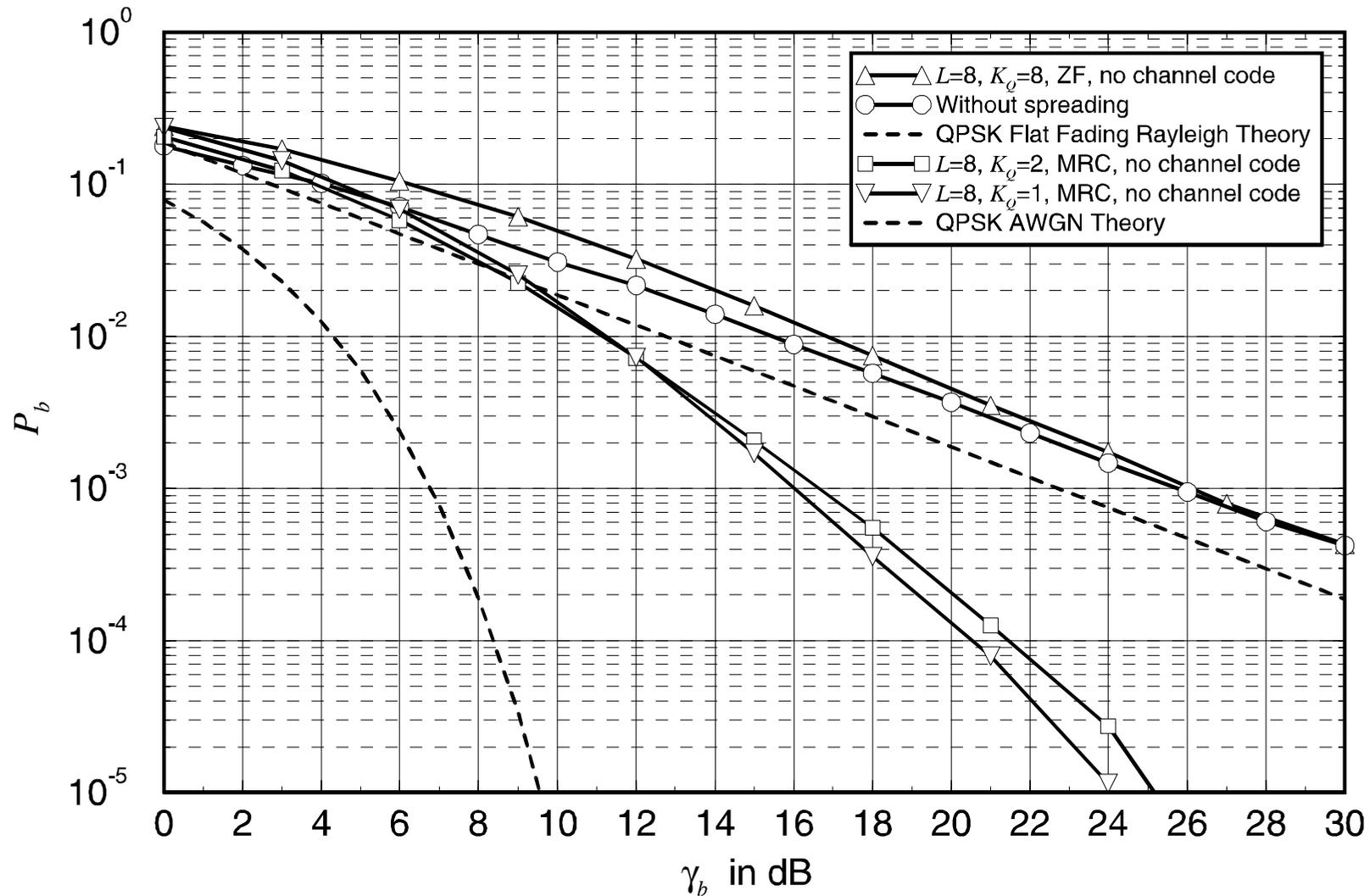
Taxi Channel QPSK Performance



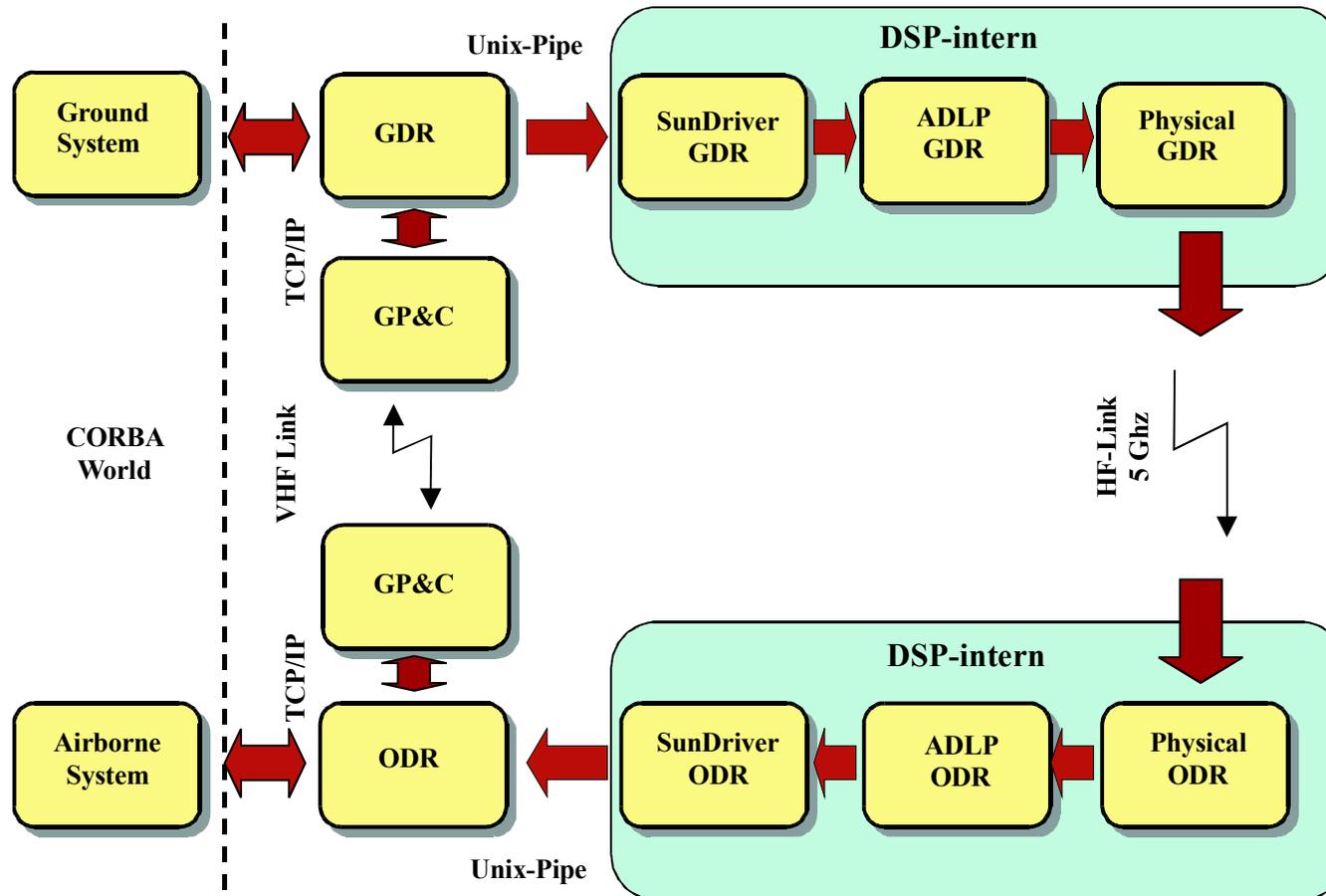
Parking Channel QPSK Performance



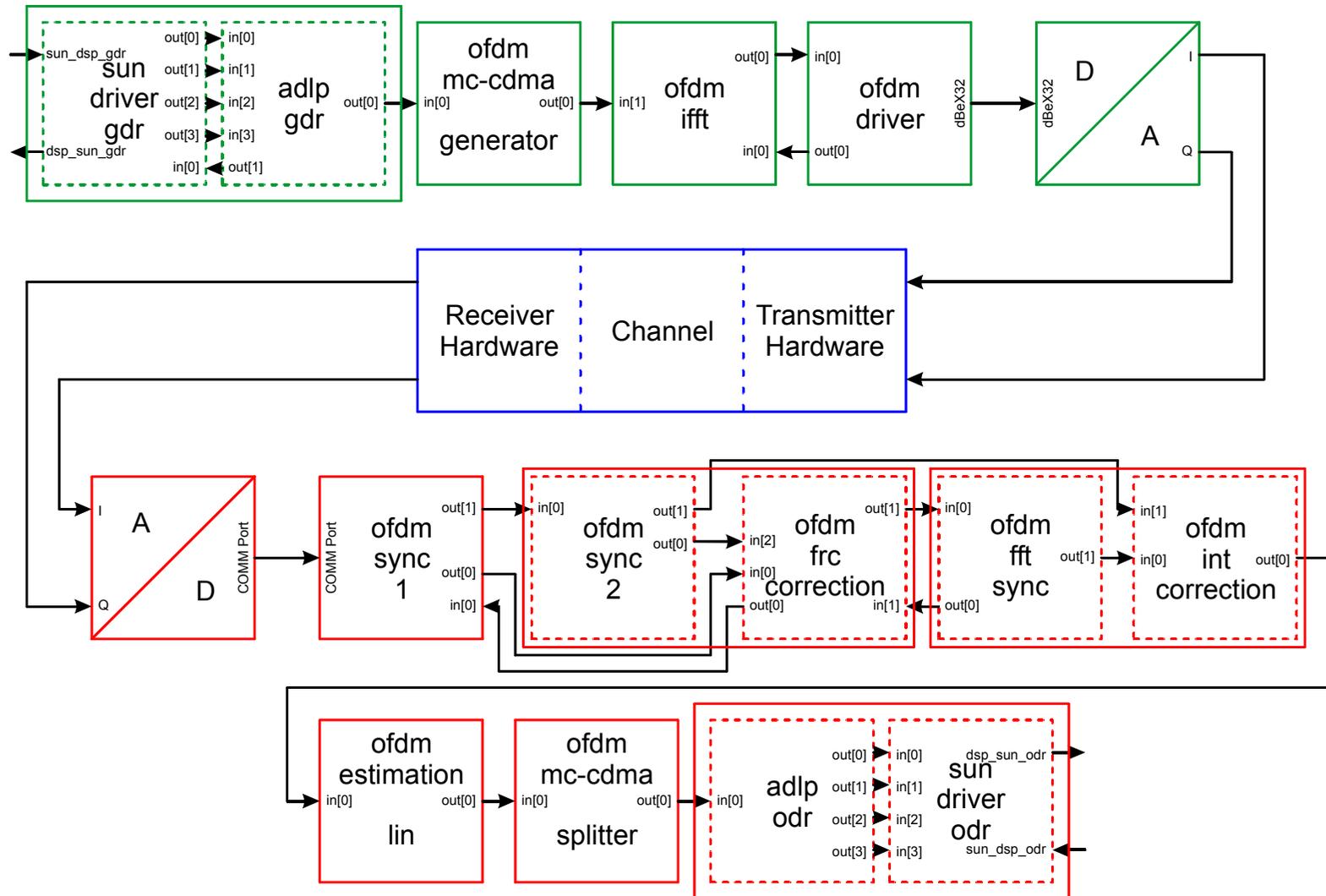
Parking MC-CDMA Performance



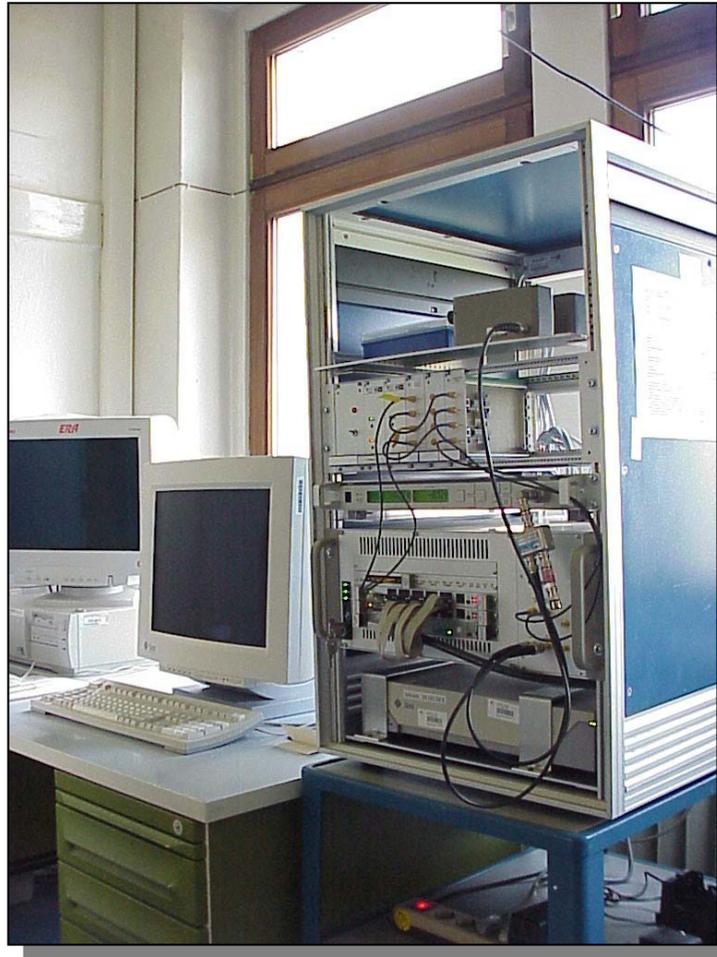
ADL Demonstrator



ADL Demonstrator - DSP



ADL Demonstrator - Tx and Rx



Transmitter

Receiver



ADL @ DLR Braunschweig

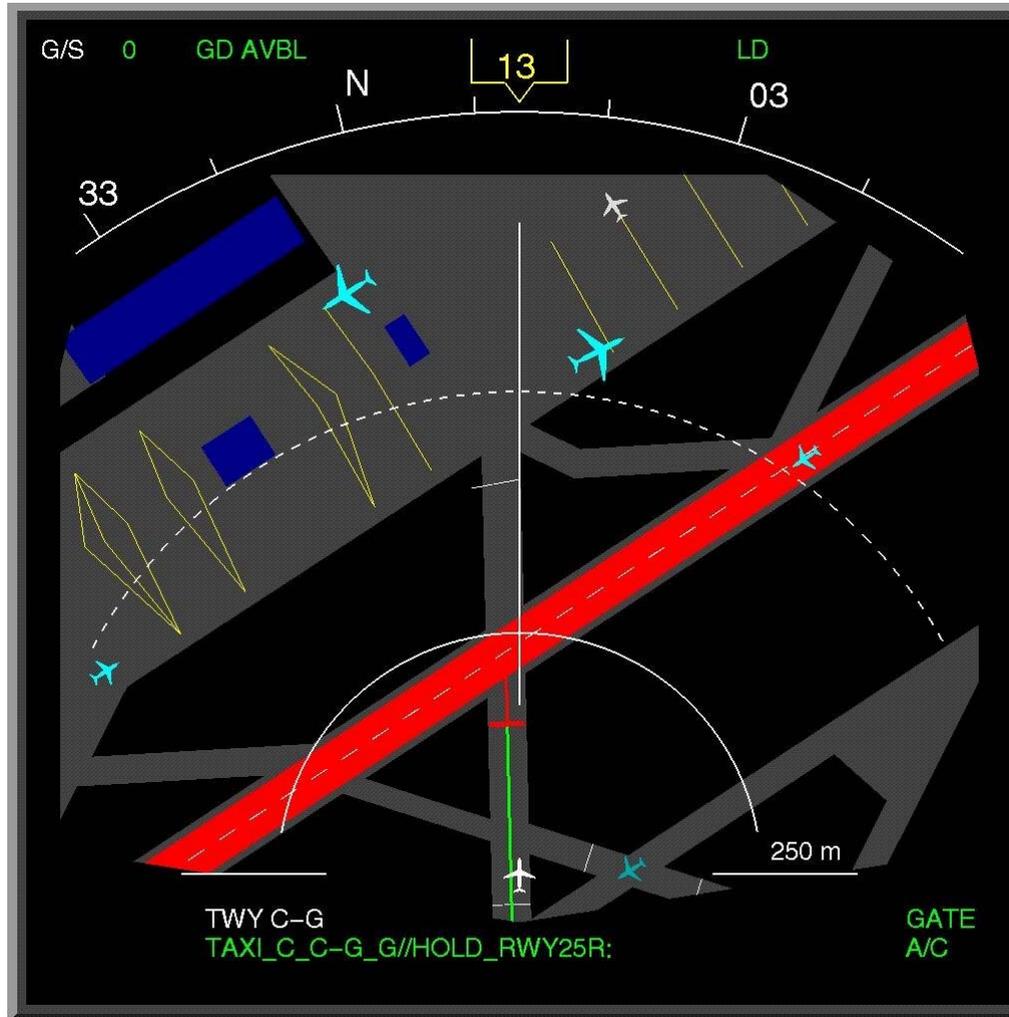


Test vehicle
with receiver inside



Tx antenna
and RF part including
high-power amplifier

Pilot Display for TARMAC

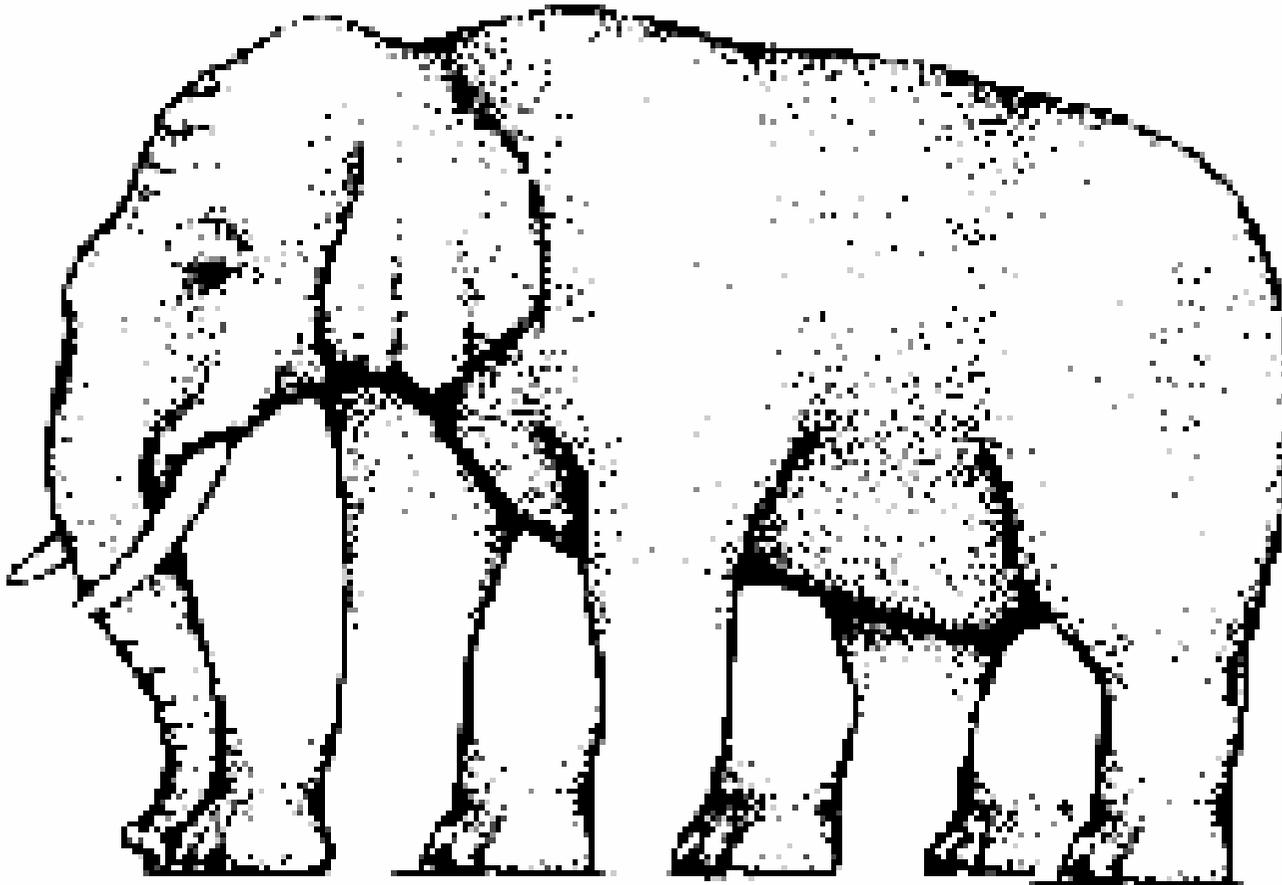


Conclusions and Outlook

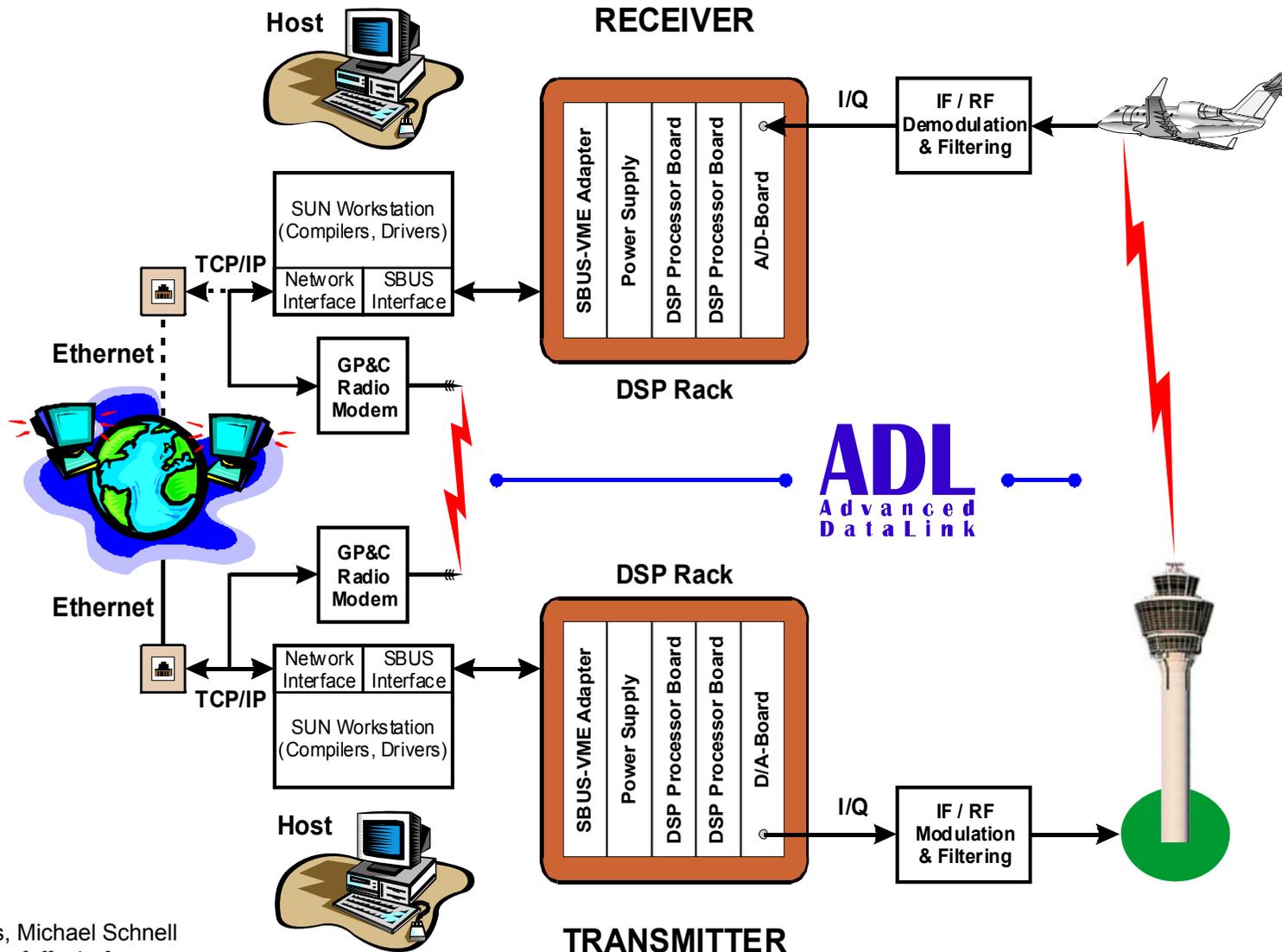


- Development of the ADL which is based on MC-CDMA for aeronautical high-rate data transmission at 5 GHz
- Evaluation of ADL design using computer simulations based on different aeronautical channel models
- Proof of suitability for critical environments
- Implementation of a demonstrator system in DSP technology for tests in real world environment
- Field tests have been carried out using a test vehicle to show the functionality and effectiveness
- Future work will concentrate on the design and implementation of an adequate backward link

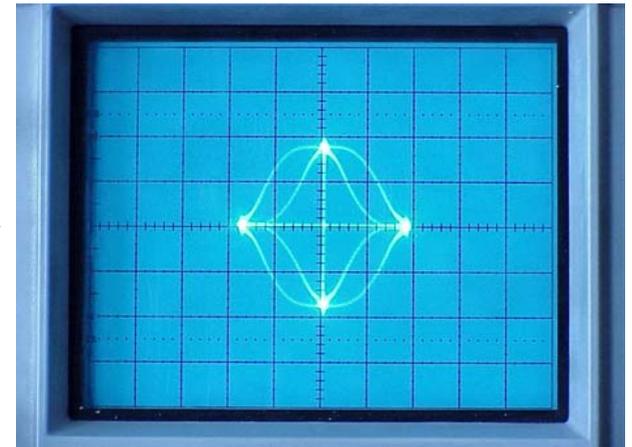
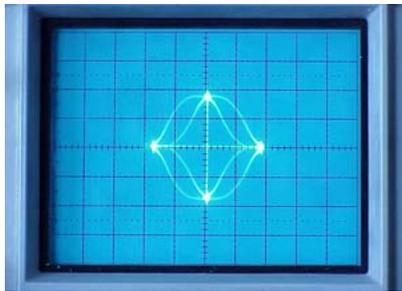
Questions



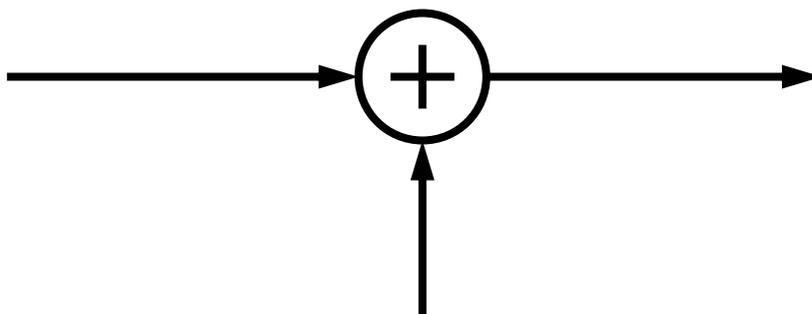
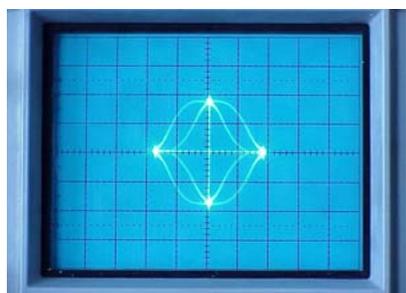
ADL Demonstrator System



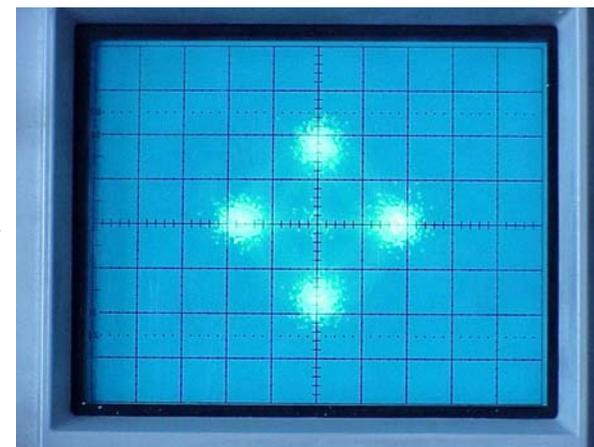
MC-System without Distortions



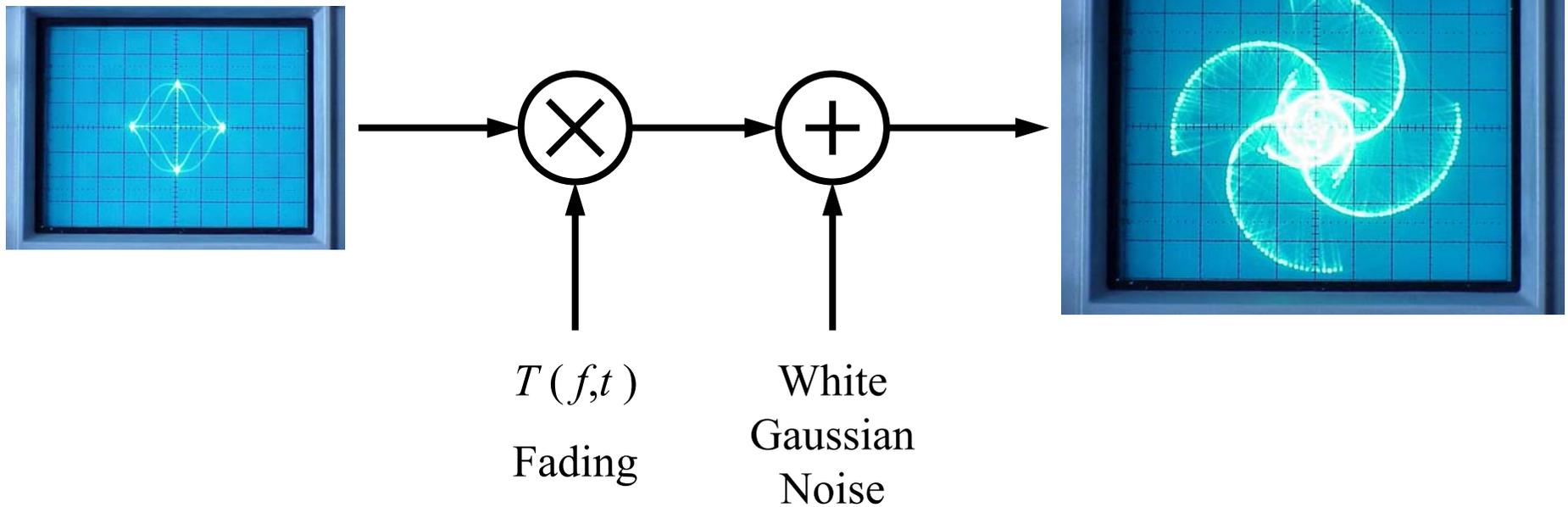
MC-System with Additive Noise



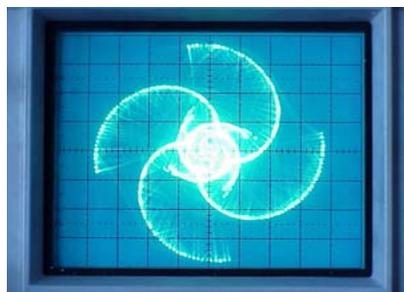
White
Gaussian
Noise



MC-System with Fading & AWGN



Received & Equalized MC-Signal



Channel
Estimation
&
Equalization

